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Highlights of the Fourth International Symposium on Free Radical Stabilization

THE FOURTH International Symposium on Free Radical Stabilization, arranged and coordinated by the National Bureau of Standards, was held in Washington August 31 to September 2.[1] More than 325 scientists attended the meetings, which emphasized fundamental research results obtained in studies of the highly reactive molecular fragments. In line with the theme of the meeting, "Trapped Radicals at Low Temperatures", papers were concerned with the properties of solids containing trapped radicals and the chemical and physical interactions involving trapped radicals at low temperatures.

This series of annual symposia has grown naturally out of the widespread interest in the trapping of free radicals, which reached a high around 1955. At this time, it became possible to trap the radicals in quantities large enough to study. Ordinarily, radicals exist for only a few thousandths of a second, in systems such as flames and hot gases. However, by freezing the products of an electric discharge at a few degrees above absolute zero, it is possible to trap free radicals in a highly excited state, in which they can be kept for hours and studied by a number of physical and chemical techniques.[2] Other methods for capturing and storing them include irradiation of material with gamma-rays, X-rays, or ultraviolet light, and bombardment with accelerated particles, such as electrons or protons.

This same intensified interest led the Department of Defense, in 1956, to sponsor a 3-yr Free Radicals Research Program at the Bureau.[3] Plans for terminating this program by the first of October provided an important reason for holding the September meeting in Washington. This gave visitors a last opportunity to view existing facilities and activities. Meetings were held at Dunbarton College, within walking distance of the Bureau grounds. A. M. Bass, Chief of the Bureau's Free Radicals Section, was symposium chairman.

The symposium consisted of five sessions in which 29 papers and five short contributions were presented. The sessions were devoted to: The NBS Free Radicals Research Program; Low Temperature Chemistry; Methods of Production of Trapped Radicals and Physical Properties of Radical-Trapping Solids; Identity and Concentrations of Trapped Radicals; and Future Trends in Trapped Radical Research.

Discussion of Bureau work was essentially limited to the first session in which the experimental and theoretical aspects of the Free Radicals Research Program were

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covered by Bureau staff members M. D. Scheer and C. M. Herzfeld, respectively. Four other survey papers summarized the following four sessions. These four papers also emphasized Bureau work, but were broader in scope and attempted to define the state of accomplishment in a number of areas. They were presented, respectively, by R. Klein, guest worker at the Bureau from Olin-Mathieson; A. Thomas, guest worker from Shell Research, Ltd.; R. Zwanzig of the Bureau; and O. Schnepp of the Bureau, on leave from the Israel Institute of Technology.[4]

One of the conclusions drawn from the conference is that emphasis is shifting from the radicals themselves to their use as a research tool. An illustration of this is the pioneering work of Klein and Scheer on the addition of H-atoms to solid olefins.[5] This discussion, included in Dr. Klein's survey paper, pointed up the increasing importance of low temperature chemistry and the part that radicals will play. Another presentation of importance in this same general area was a paper by J. M. Flournoy, L. H. Baum, S. Siegel, and S. Skolnik of the Aerojet-General. Their kinetic studies of the disappearance of hydroxyl radicals in ice at 77° K showed that the rate determining processes were diffusion or migration of the radicals through the ice.

The session on the Production of Trapped Radicals and the Properties of Radical-Trapping Solids brought out the importance of the physical properties of the matrix. At present, the mechanism of deposition and condensation of gas on a surface at liquid helium temperatures is very poorly understood. The problem was pointed up by R. T. Brackmann and W. L. Fite of General Atomic, who reported that in experiments with a hydrogen atomic beam they found no evidence of trapped species at liquid helium temperatures even when spin-alined atoms were used. However, using molecular hydrogen at flow rates of the order of 10^{18} particles per second, they observed periodic energy releases occurring every few seconds during deposition. M. Windsor, guest worker at the Bureau from the Space Technology Laboratories, suggested that these results might be caused by water vapor impurities, and described similar pulsing observations with discharged gases. He pointed out that the very presence of trapped atoms and free radicals in a matrix, and the disorder thereby introduced, are likely to reduce the thermal conductivity by several orders of magnitude. It is thus possible for large temperature gradients to exist between the cold substrate and the growing surface of the deposit. An interesting attempt to trap organic free radicals in an ionic crystal matrix of potassium chloride was described by H. T. J. Chilton and G. Porter of Sheffield University. However, their results appear to show that the trapping takes place in microcrystals of the solute rather than in the matrix itself.

Several papers on spin resonance were presented in the session on Identity and Concentration of Trapped Radicals. G. Pimentel of the University of California and R. Livingston of the Oak Ridge National Laboratory agreed that the sensitivity of this method requires that gross chemical analysis be performed on ESR (electron spin resonance) specimens to confirm the assignments of spectra. It was also suggested in discussion that, since the interpretations of polycrystalline spectra are ambiguous, more work be done with single crystals, on the order of that reported by C. A. McDowell and A. Horsfield of the University of British Columbia. H. Bent from the University of Minnesota described new oxides of nitrogen which, like free radicals, can be trapped at low temperatures in a thermodynamically unstable form. In his review, Dr. Zwanzig said that heat release and ESR measurements both lead to figures of a few tenths of a percent for maximum stable concentrations of free radicals.

Another important area is that of Interaction of Free Radicals with Solids, which was the subject for the last session. By using trapped radicals as a tool, and observing the effect of molecular environment on their molecular energy levels—as reflected by changes in optical spectra and ESR spectra—it is possible to get information about the structure of the matrix in the immediate vicinity of the trapped radicals. S. N. Foner of the Johns Hopkins University Applied Physics Laboratory found evidence for multiple trapping sites for hydrogen atoms in various matrices of rare gases at 4° K. M. McCarty and G. W. Robinson of Johns Hopkins University used a Lennard-Jones potential to account for the interaction between rare gas matrices and small radicals, observed by means of their optical spectra. The subject of the nitrogen-atom afterglow also came in for much discussion. R. A. Hemstreet and J. R. Hamilton from the Linde Company described kinetic observations of the isothermal decay of the alpha bands. They found it possible to restimulate the glow by raising the temperature of the sample from 4° in steps up to 30° K. As the glow dies off at approximately the same rate at each temperature, it is apparent that atoms are trapped in sites varying over a range of energy. Although the observed emission spectra can be correlated well with the emission from excited nitrogen atoms, the mechanism by which these excited atoms are formed is still not understood.

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[1] Fourth International Symposium on Free Radical Stabilization, *NBS Tech. News Bul.* **43,** *62 (1959)*; Plans for the Fourth International Free Radicals Symposium, *NBS Tech. News Bul.* **43,** *139 (1959)*.

[2] Low temperature storage of free radicals, *NBS Tech. News Bul.* **40,** *112 (1956)*; Patent for free-radical stabilization, *NBS Tech. News Bul.* **43,** *175 (1959)*.

[3] Free Radicals Research Program, *NBS Tech. News Bul.* **41,** *1 (1957)*.

[4] *All survey papers will be published in a monograph. For further information write A. M. Bass, Free Radicals Section, National Bureau of Standards, Washington 25, D.C.*

[5] Studies of reactions with low activation energies, *NBS Tech. News Bul.* **43** *(see p. 206)*.

New Gamma-Ray Radioactivity Standards

THE National Bureau of Standards announces the availability of three new gamma-ray radioactivity standards. Strontium-85, niobium-95, and mercury-203 can now be obtained in approximately 5 g of solution, sealed in glass ampoules.

These gamma-ray emitters are issued as part of the Bureau's program to supply standards in all areas of the physical sciences. Radioactivity standard samples,[1] such as these, are widely used in physics, chemistry, biology, and medicine to control processes and to maintain the accuracy of equipment and apparatus.

For the most part, nuclides issued as radioactivity standard samples are used as calibrated working standards for the same nuclide. Strontium-85 is an exception to this rule. This particular nuclide emits gamma rays with an energy of 513 kev, which is almost identical to the energy of positron annihilation radiation. Strontium-85 can therefore be used to calibrate instruments for positron emitter measurements. Strontium-85 has a half-life of 65 days.

Niobium-95 emits 1 beta particle (E_{max}=160 kev) and 1 gamma ray (E=768 kev). Its half-life is 35 days. Mercury-203 also emits 1 beta particle (E_{max}=208 kev) and 1 gamma ray (E=279 kev). In addition, X-radiation is present. Mercury-203 has a half-life of 46.5 days.

As of August 15, 1959, the strontium-85 sample had a total nominal activity of 2×10^6 disintegrations per second, niobium-95 had 6×10^5 disintegrations/sec, and mercury-203 had 10^7 disintegrations/sec. As these standards, because of their high activities, can be issued only under the special licensing provisions of the Atomic Energy Act of 1954, it is required that a copy of the purchaser's current AEC by-products material license be on file at the Bureau. The new strontium, niobium, and mercury standard samples may be obtained from the Radioactivity Section, National Bureau of Standards, Washington 25, D.C. for $27.00 each.

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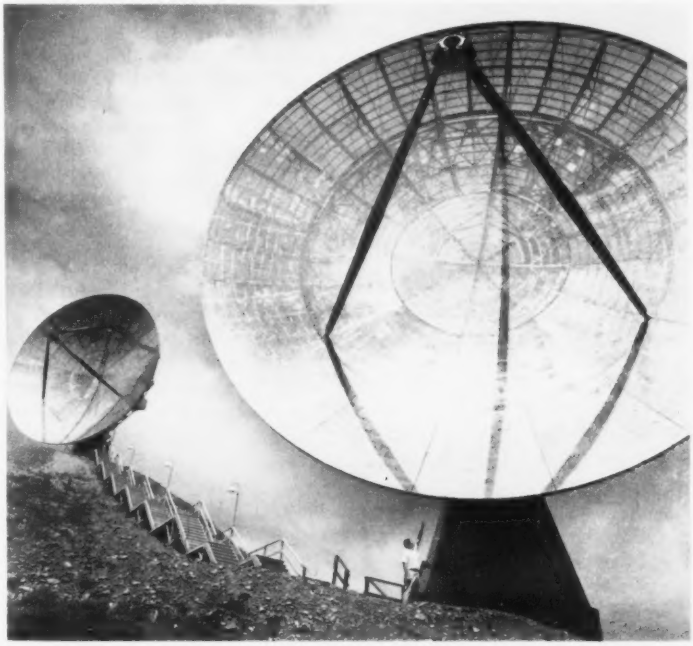
[1] *Further information is contained in* Standard Materials *NBS Circ. 552 (third edition), which may be obtained by writing to the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (35 cents).*



Precision Antennas Set Up for Radio Propagation Research

Two of the three 60-ft diam elevation azimuth paraboloidal antennas recently installed in a radio propagation research program for the U.S. Air Force. The Bureau's Central Radio Propagation Laboratory in Boulder, Colorado, will employ these antennas to measure the refraction of radio waves through the earth's atmosphere. The antennas have been built to very close tolerances to narrow the beam width, and thus increase the resolving power. The accuracy with which the antennas are rotated on their axes is also carefully controlled to prevent any disturbance in reception.

STANDARDIZING FUEL FLOW RATES

TO PROVIDE an accurate basis for the measurement of fuel flow rates in aircraft fuel systems, the Bureau has been conducting a liquid-flow rate standardization program for the Navy Bureau of Aeronautics. Directed by M. R. Shafer of the NBS staff, this program has included both a study of current calibration techniques [1] and the operation of calibration apparatus to serve as a reference for the aviation industry.

Precise instrumentation and test techniques are essential in the test and adjustment of the newer aircraft engines. Millions of dollars are spent each year testing these engines and their fuel-metering accessories. As flowmeters are used extensively in such work,

Flowmeter calibration apparatus, showing scale for measuring collected fuel, electronic timer (on panel above scale), and electronic counter (lower right) which records the number of turns of the rotor inside flowmeter.

it has become desirable to provide reference facilities by which the accuracy of flowmeter calibrators at other locations can be verified. To provide this reference, the Bureau operates calibration apparatus accurate to 0.2 percent or better for liquid hydrocarbon flow rates in the range of 20 to 100,000 lb/hr.

The Bureau is also interested in obtaining suitable flowmeters for use as transfer references for the accuracy evaluation of flowmeter calibrators at other locations. Such reference meters should have a repeatability of ± 0.1 percent or better, and all factors which may influence their performance should be known and controlled.

Among the many different flowmeters available, the glass-tube, variable-area type is fairly adequate for reference work in the range 20 to 20,000 lb/hr. The turbine or propeller-type meters are reasonably satisfactory for the range 2,000 to 100,000 lb/hr and up. Extremely precise results can be obtained on these meters only with low-viscosity liquids. In applications involving high-viscosity liquids, such as lubricating and hydraulic oils, positive displacement and orifice meters give better results for reference work.

The turbine meter is used extensively in aircraft work. This meter consists of a tubular section of pipe, threaded at each end, for convenient insertion into the fuel line at any desired location. Inside this section is a small, many-vaned rotor having a velocity of rotation proportional to the volume flow rate. The rate of rotation is sensed by a magnetic coil, imbedded in the wall, which generates electrical pulses having a frequency directly proportional to the rotor velocity. These pulse signals are converted to either flow rate or total flow by appropriate readout instrumentation.

Calibrators Compared

The Bureau constructed a static flowmeter calibrator to determine whether significant absolute errors existed in other calibration techniques. This apparatus, accurate to within ± 0.15 percent, was used to evaluate the accuracy of dynamic calibrators, which have the advantage of speed and convenience of operation.

The comparative tests between the Bureau's static apparatus and three different types of dynamic calibrators showed that agreement within ± 0.15 percent could generally be obtained between different methods of flowmeter calibration. One of the dynamic calibrators is now in use at the Bureau. It was carefully compared with the static apparatus, and good agreement was found several times over a period of 2 years.

The Bureau no longer uses the static apparatus for calibration work with liquid hydrocarbons because of space and operating time limitations. However, the dynamic calibrator now in use is known to be accurate to within ± 0.2 percent for the range 20 to 100,000 lb/hr. Static calibration apparatus is still maintained at the Bureau's hydraulics laboratory, where precise determinations can be made using water as the test fluid.

Work on the different calibration procedures provided useful data concerning techniques required for precision calibration of flowmeters. This information will be outlined briefly, beginning with a description of the operation of the static calibrator and followed by other factors which should be considered when working to high accuracies.

Operation of the Static Calibrator

The static calibration apparatus measured flow rate by determining the weight of liquid collected in a weigh tank during a measured time interval. The flowmeter to be calibrated discharged through a flow-control throttling valve into a diverter which directed the liquid either to return-to-storage or to the weigh tank. The diverter actuated an electronic timer at the midpoint of its travel, thus automatically determining the time interval the liquid was diverted to and collected in the weigh tank.

The weight determinations were performed under the static condition of no flow into the weigh tank, which was mounted on a 5,000-lb-capacity platform scale of a self-contained lever type equipped with suspension main-load bearings. The scale was modified to give readings to 0.05 lb and was calibrated with 50-lb test weights known to be accurate to ±40 grains. The sensitivity, precision of calibration, and constancy of the scale as determined by tests were such that minimum net weights of 400 lb could be measured to an absolute accuracy better than 0.05 percent.

The electronic timer indicated in units of 0.001 sec and was calibrated against the standard time signal broadcast by the Bureau's radio station WWV, accurate to 1 part in 100 million.

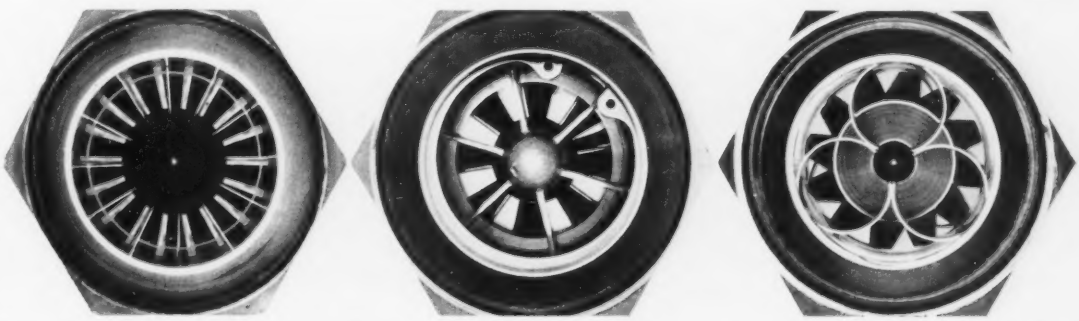
Factors to be Considered

Flowmeter performance is affected by the density, viscosity, and temperature of the liquid; flow disturbances; and vapor pressure with its resultant cavitation and loss of liquid by evaporation. All of these must be considered in precise calibration work. The effects of density can usually be determined by mathematical analysis. Viscosity effects can be established only through calibration tests and these are especially pronounced in the smaller size meters. Temperature exerts its influence through its effect upon the configuration of the meter and upon the physical properties of the liquid.

Upstream flow disturbances originating within the pumps and supply piping may sometimes affect flowmeter performance by as much as 1 percent or more. Some success has been obtained using flow straighteners containing bundles of small tubing placed in a larger tube connected to the entrance of the meter under test. Although these flow disturbances are not usually significant in conventional applications, they must be considered in reference meter work where repeatability of about 0.1 percent is required.

Vapor pressure of the liquid is an important consideration because of the possibility of cavitation or vapor formation within the meter under test and loss by evaporation of the liquid from the weigh tank. Meter cavitation is eliminated by maintaining the fuel within the meter at a sufficiently high pressure level. Loss from the weigh tank by evaporation is a definite problem when working with high vapor pressure liquids, such as gasoline. The ideal solution appears to be a pressurized weigh system, but it would introduce many additional complications.

The Bureau is continuing its study of flow rate measuring techniques in an attempt to find flowmeters more suitable for use as transfer references. Also included in this program will be the continued evaluation of newly developed flowmeters for telemetering, computer, and automatic recording and control applications.



Entrance-end views of typical turbine flowmeters, showing flow straighteners and rotor vanes. The vanes appear black in the photographs.

[1] *For further technical information, including a discussion of dynamic calibration techniques, see* Liquid-flowmeter calibration techniques, *by M. R. Shafer and F. W. Ruegg, Trans. ASME October 1958, Paper No. 57–A–70.*

Studies of Reactions With Low Activation Energies

A SIMPLE quantitative method for studying at least one class of low-activation-energy reactions has developed out of the Bureau's Free-Radicals Research Program, sponsored by the Department of Defense. This work, carried out by R. Klein [1] and M. D. Scheer, is of particular interest because systems with low activation energies provide data on the mechanisms and kinetics of certain elementary chemical reactions.

In contrast to most chemical reactions which require elevated temperatures to surmount an energy barrier, low-activation-energy reactions will occur at very low temperatures. Certain classes are even observable at liquid-nitrogen temperatures or lower. These include radical-radical, radical-molecule, ion-ion, and ion-molecule interactions. However, until recently, all of these systems, with their potentialities for yielding fundamental data, have been extremely difficult to set up. The Bureau's studies have provided a simple method for establishing reactions of the radical-molecule type.

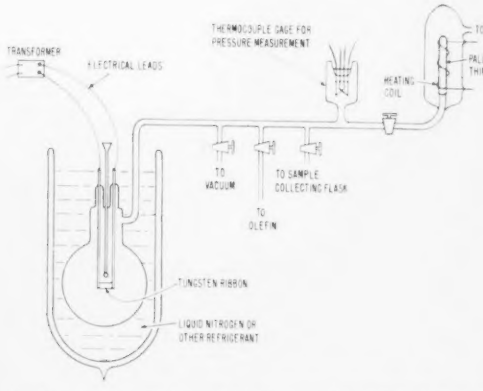
In producing such a reaction the radical is prepared in the gas phase and then made to diffuse into a solid capable of reacting with it. By this technique, it was found, for example, that hydrogen atoms can diffuse into solid olefins; react with some, such as ethylene, propylene, and butene-1, at 77° K; and react with still others at slightly higher temperatures.[2] It was also demonstrated that hydrogen atoms react with solid oxygen at 20° K,[3] with the halogens at temperatures at least as low as 77° K, and with certain aromatics such as toluene or styrene and its derivatives, also at 77° K.

The experimental technique used in these investigations is quite simple. For example, an olefin, such as butene-1, is uniformly deposited as a thin film on the inner surface of a spherical bulb immersed in a refrigerant. In the center of the bulb a tungsten ribbon is mounted just as in an ordinary light bulb. Molecular hydrogen, introduced until the pressure reaches 100 μ, is dissociated on the heated filament. Within a time interval which may be as short as 5 sec depending on the filament temperature, a reaction between hydrogen atoms formed and the deposited olefin takes place. This is shown by the pressure of hydrogen in the bulb, which drops from 100 μ to less than 1 μ. The rate of reaction is proportional to the pressure drop during a given "on" time of the tungsten ribbon. The products of the reaction can be analyzed either by infrared techniques or, after warmup, by gas chromatography and mass spectrometry.

The ability to study chemical reactions quantitatively in the low-temperature region promises to stimulate a new field of inquiry into chemical behavior. Subtle differences in reactivity, undetectable at ordinary temperatures, are quite evident at low temperatures. In addition, complicating secondary reactions can be avoided.

In the case of olefins, a difference in rates of reaction with hydrogen atoms are easily observed. Solid propylene and solid butene-1 react readily at 77° K while hexene-1 reacts at observable rates only above 130° K and butene-2 shows no activity even at its melting point. These results show the advantages of this method over gas-phase investigations at higher temperatures where differences in rate cannot be determined.

The H-atom addition to solid butene-1 at 77° K is an interesting example of some of the processes that can be investigated in detail. For example, the question of



Studying the reaction of H-atoms with solid olefins at low temperatures. M. D. Scheer raises a Dewar of liquid nitrogen up to a flask containing the olefin. Molecular hydrogen will be dissociated by the glowing tungsten ribbon filament inside the flask. Diagram of equipment is shown above.

whether the hydrogen atoms need to possess translational energy corresponding to temperatures above the low temperature of the solid was answered by a simple experiment. Inert olefins, such as propane or butane, were deposited on top of the butene-1 so that H-atoms would be cooled to liquid nitrogen temperatures before they reached the reactive olefin. It was found that these coatings do not affect the reaction rate until their thickness becomes greater than 1,000 molecular layers.

Determining the dependence of the reaction rate was also a relatively easy task. This time the propane or butane was combined in a solid solution with butene-1. With a constant concentration of butene-1, reaction rates are proportional to various H-atom concentrations; with a constant H-atom concentration, rates are proportional to the butene-1 concentration.

From a study of the products formed, it was established conclusively that H-atom addition occurs to the terminal carbon. With butene-1, for example, the addition of an H-atom gives a secondary butyl radical. The radicals formed may then react either with another H-atom or with each other. If a second atom adds to the butyl radical, butane is formed. On the other hand, this second atom may abstract hydrogen from the butyl radical to form trans-butene-2. The radicals themselves may dimerize to form 3, 4 diemthyl hexane, or they may disproportionate to form butene and butane. It is the exclusive formation of the 3,4 dimethyl hexane as the dimer product which shows that H-atom addition always occurs to the terminal carbon of the double bond.

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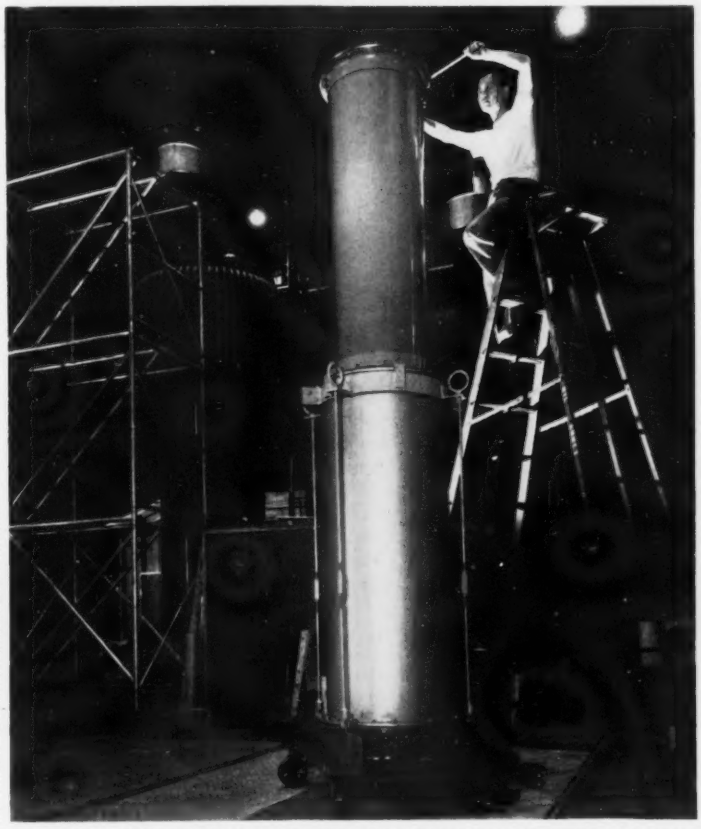
[1] *Guest worker at the Bureau from Olin-Mathieson.*

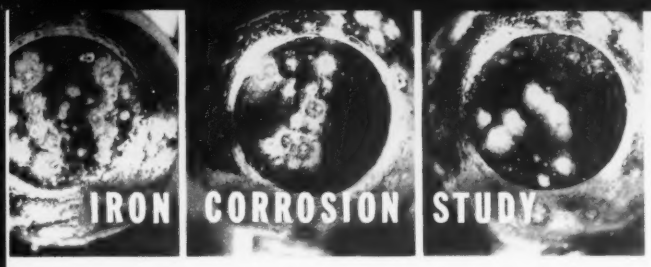
[2] *For further information, see* The reaction of hydrogen atoms with solid olefins at –195°, *by Ralph Klein and Milton D. Scheer, J. Phys. Chem.* **62,** *1011 (1958)*; The addition of hydrogen atoms to solid olefins at –195°, *by Ralph Klein and Milton D. Scheer, J. Am. Chem. Soc.* **80,** *1007 (1958)*.

[3] The reaction of hydrogen atoms with solid oxygen at 20° K. by *Ralph Klein and Milton D. Scheer, J. Chem. Phys.* **31**, *278 (1959)*.



German Transformer Tested

The largest of four standard transformers from the Physikalisch Technische Bundesanstalt (the West German national laboratory) which were recently tested by the Bureau. Ratio and phase-angle measurements were made as part of this international comparison of standards for alternating current and voltage measurements. In addition to the United States and Germany, Canada participated in these tests, which included current measurements from 0.1 amp to 10,000 amp and voltage measurements from 3,000 v to 230,000 v. W. Sze of the Bureau staff is shown preparing the transformer for the test.



Pitting corrosion tendency of high-purity iron was found to depend on the crystallographic orientation of the metal. *Left to right*, dodecahedral, cubic, and octahedral faces of the same iron crystal after exposure for 3 hr in distilled water. Note the higher rate of pitting on the dodecahedral surface.

THE Bureau, in a continuing program of corrosion research partly supported by the Corrosion Research Council, recently investigated the influence of crystallographic orientation on the pitting of iron in distilled water.[1] In experiments conducted by Jerome Kruger, pitting activity was found to proceed at a different rate on each of the principal crystal planes exposed on the metal surface. These results, similar to those previously obtained in Bureau studies on copper and aluminum,[2] are expected to have practical applications in developing better methods for combating corrosion.

Because of our limited fundamental knowledge of corrosion processes, corrosion problems must today be attacked mainly by empirical methods. The present study was undertaken to provide additional basic information on the corrosive properties of metals, and the mechanisms involved in the destructive process.

Initial experiments were conducted with iron single crystals grown in the shape of a sphere from an ingot having 2,460 ppm of impurities. The specimens, ⅜ in. in diameter, had flat surfaces cut parallel to the [100] (cubic), [110] (dodecahedral), and [111] (octahedral) planes. The surfaces were polished first mechanically and then chemically with a commercial solution.

When a single crystal thus prepared was exposed for 3 hr in a vessel of distilled water at room temperature, the [110] plane was observed to have the greatest number of pits per unit area. The [100] had approximately one-half, and the [111] approximately one-quarter as many pits as the [100] plane. The number and location of pits were not always the same for different time intervals of exposure; however, the order of pitting for the three planes remained the same in the seven tests that were carried out.

In another series of tests, the specimens were etched with a dilute solution of hydrochloric acid after mechanical polishing, to find out whether the commercial solution had influenced previous results. In addition, the flat surfaces of the specimens were exposed in either a horizontal or a vertical position, to check the effect of this factor on corrosion of the surface. In all cases, the same order of pitting activity was observed.

Additional studies were carried out with an iron of higher purity (235 ppm of impurities), from which specimens were prepared having large grains of many different surface orientations. The grains whose orientations were near that of the [110] crystallographic plane pitted every time, while those grains nearer the [111] and [100] orientations pitted only once or not at all during the course of five tests. It was observed that the general level of pitting attack was lower for the purer iron specimens.

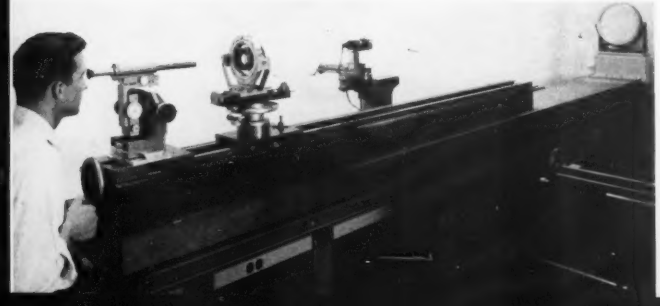
[1] *For further details, see* The influence of crystallographic orientation on the pitting of iron in distilled water, *by Jerome Kruger, J. Electrochem. Soc.* **106,** *736 (1959).*

[2] Some basic corrosion research at NBS, *by J. Kruger, Ind. and Eng. Chem.* **50,** *55A (1958);* The oxide films formed on copper single crystal surfaces in pure water: I. Nature of films formed at room temperature, *by J. Kruger, J. Electrochem. Soc.* **106,** *No. 10 (1959);* Influence of crystallographic orientation on the corrosion rate of aluminum in acids and alkalies, by T. H. Orem, *J. Research NBS* **58,** *157 (1957) RP2748.*

Evaluating Lens Distortion with the Nodal Slide Bench

INCREASED accuracy in distortion values for photogrammetric lenses can be achieved with the nodal slide bench, according to a Bureau study, partially supported by the U.S. Air Force.[1] An examination of the step-by-step process used with this instrument discloses that possible errors in adjustment can have an appreciable effect on the final values obtained for distortion. When the magnitudes of these errors are ascertained, distortion values formerly difficult to determine more closely than to the nearest 20 μ are now determined to within 2 μ. These results may help to point the way to additional applications for photogrammetry, which now is widely employed in planning large-area constructions such as new roads and highways.

The nodal slide bench, one of the first instruments developed for measuring the optical constants of lenses, has provided an adequate method for evaluating lenses with moderate amounts of distortion. However, higher accuracy has been sought to evaluate the so-called "distortion-free" lenses used in photogrammetric mapping. Even a small amount of uncompensated distortion in these lenses may not only influence the relative location of separated objects on a map but may also produce a variable photographic scale. In an effort to obtain increased accuracy with the nodal slide method, F. E. Washer and W. R. Darling, of the optical instruments



George Ofelt adjusts the nodal slide optical bench used to measure lens distortion. Equipment includes, *left to right*: Viewing microscope for measuring the transverse displacement of the image formed by the lens; nodal slide holding the lens under test; target reticle holder and illuminating system; parabolic mirror.

laboratory, undertook an extensive study of the effect possible errors of adjustment could have on the final values observed for distortion.

The distortion present in a series of lenses was first evaluated with the nodal slide. This movable assembly on an optical bench holds the lens under test, and when the lens is properly alined, the axial image formed of an illuminated target reticle coincides with the object plane of a viewing microscope. For an ideal lens, rotated through the same angle to the right and left of the original setting, the values found should be equal. However, in the lenses tested some asymmetry was generally noted.

Through a mathematical analysis of the measurements made, three principal factors were identified which contributed to the asymmetry. They were: (1) Misalinement of the collimator (parabolic mirror and illuminated target reticle) with respect to the bench ways; (2) transverse displacement of the rear nodal point of the lens from the center of rotation of the nodal slide; (3) angular deviation arising from prism effect on the lens combined with a compensating transverse displacement of the nodal point.

Even though all three factors may be present simultaneously, it was possible to isolate each one and compute its magnitude separately. The values thus obtained were then compared with the values previously derived, to check the consistency of the initial set of observations. It was found that if the observed values coincide with the computed values, or if the asymmetry is a smooth function of the angle through which the lens is rotated, the initial measurements are self-consistent, and can be relied upon to yield highly accurate values of distortion.

[1] *For further technical details, see* Factors affecting the accuracy of distortion measurements made on the nodal slide optical bench, *by Francis E. Washer and Walter R. Darling J. Opt. Soc. Am.* **49**, 517 (1959).

Standards of Spectral Radiant Intensity

A SIMPLE procedure for realizing standards of spectral radiant intensity has been devised by L. E. Barbrow, chief of the photometry and colorimetry laboratory.[1] By applying tabulated values to a tungsten-filament lamp standard that has been calibrated for luminous intensity at a specific color temperature, the lamp can easily be converted into a standard of spectral radiant intensity within the visible spectrum.

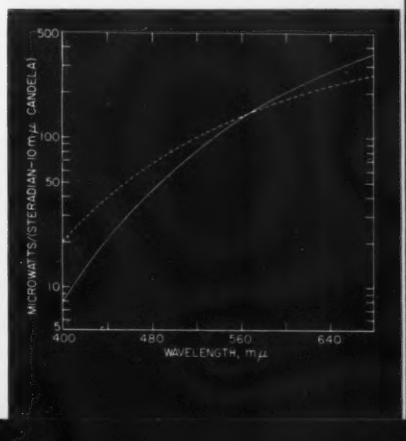
Spectral radiant intensities for one candela of luminous intensity at seven different color temperatures. Values are given in microwatts per steradian in 10-mμ bands throughout the visible spectrum

Wavelength	2,300° K	2,400° K	2,500° K	2,600° K	2,700° K	2,800° K	2,854° K
mμ							
400	8.0	9.8	11.7	13.9	16.2	18.6	20.0
410	10.4	12.5	14.7	17.2	19.8	22.5	24.1
420	13.3	15.7	18.2	21.0	23.9	26.9	28.6
430	16.7	19.4	22.3	25.4	28.5	31.8	33.6
440	20.7	23.7	27.0	30.3	33.7	37.2	39.1
450	25.3	28.7	32.2	35.8	39.4	43.1	45.1
460	30.7	34.4	38.1	41.9	45.7	49.5	51.5
470	36.8	40.7	44.6	48.6	52.5	56.3	58.4
480	43.7	47.8	51.9	55.9	59.8	63.7	65.7
490	51.4	55.6	59.7	63.7	67.6	71.4	73.5
500	60.0	64.2	68.3	72.2	76.0	79.6	81.6
510	69.4	73.5	77.5	81.2	84.8	88.2	90.0
520	79.8	83.7	87.4	90.8	94.1	97.2	98.8
530	91.0	94.5	97.9	101	104	106	108
540	103	106	109	111	114	116	117
550	116	118	121	123	124	126	127
560	130	132	133	134	135	136	136
570	145	145	146	146	146	146	146
580	160	160	159	158	157	156	156
590	177	175	173	171	169	167	166
600	194	190	187	183	180	177	176
610	212	206	201	196	192	188	186
620	230	223	216	210	204	198	196
630	249	240	231	223	216	209	206
640	269	257	246	236	227	219	215
650	290	275	262	250	239	230	225
660	310	293	277	263	251	240	234
670	332	311	293	277	262	250	244
680	353	329	308	290	274	260	253
690	375	348	324	303	285	269	262
700	397	366	340	317	296	279	270

The luminous intensity of 2 light sources, such as a vacuum-tungsten lamp and a gas-filled tungsten-filament lamp, may be identical. However, because they have different color temperatures, the energy they radiate, wavelength by wavelength in the visible spectrum, will not be the same. For certain purposes, such as the calibration of the spectral response of photosensitive receivers, or the determination of the spectral emittance of television screens in absolute terms, a need has arisen for standards of spectral radiant intensity.

To provide such standards, spectral intensity values were found for one candela of luminous intensity at 10-mμ intervals over the wavelength region from 400 to 700 mμ. These values were computed for 7 color temperatures ranging from 2,300 to 2,854° K. With this table, spectral radiant intensities for a calibrated lamp are obtained merely by multiplying the candlepower of the lamp by the values listed under the lamp's color temperature. As the uncertainity of spectral data thus derived is probably no greater than 3 percent over the visible spectrum, lamps calibrated for luminous intensity and for color temperature will provide a high degree of accuracy when used as spectral radiant intensity standards.

[1] *For further technical details, see* Memorandum on a procedure for obtaining spectral radiant intensities of tungsten-filament lamps, *by Louis E. Barbrow, J. Opt. Soc. Am.* **49**, *No. 11* (1959).



Ratio of spectral radiant intensity to luminous intensity of two light sources, one at color temperature 2,300° K (typical of vacuum tungsten-filament lamps), the other at 2,854° K (typical of gas-filled tungsten-filament lamps). Ratio of candlepowers of the two sources is equal to the ratio of their spectral intensities at 570 μ, as shown by intersection of the two curves.

Meteor Burst Communication System

AN experimental radio communication system that uses meteor trails for two-way message transmission has been developed by the Bureau's Boulder (Colo.) Laboratories under the sponsorship of the Air Force Cambridge Research Center. With this system, messages have been sent at speeds up to 4,800 words a minute—80 times the present speed of transmission by teletype.

The system resulted from a 3-yr investigation, conducted by R. J. Carpenter and G. R. Ochs of the NBS Central Radio Propagation Laboratory, to determine the feasibility of a long-distance vhf communication system based on reflections from meteor trails. Results of the study indicate that intermittent meteor-burst communication can compete effectively with other long-distance systems, and that it is relatively free from ionospheric disturbances which affect long-distance communication in the high frequency range.

Millions of tiny meteors enter the earth's atmosphere every day, only to burn up before they can fall to the ground. When a meteor reaches the lower part of the ionosphere, the heat due to air friction vaporizes some of the meteoric material, creating a trail of electrons and ionized atoms behind the meteor about 15 miles long. As this trail reflects radio waves, it causes short-time enhancement of radio signals.

Because of the transient nature of meteor trails, they cannot be used continuously to transmit radio signals. Thus a communication system using this phenomenon requires a new approach to message handling and control. The system must operate intermittently at very high speed, and must go into operation automatically when a suitable meteor trail is available for signal enhancement. Obviously there must be some provision for storing messages during periods when no suitable meteor trail is available.

In recent years the overcrowding of the high-frequency bands traditionally used for long-range communication has stimulated investigation of various vhf and uhf communication systems. One result of this work has been the development of ionospheric forward scatter propagation [1]—another promising vhf communication system. In contrast to meteor burst communication, forward scatter provides a continuous signal. However, the meteor burst system has the advantages of lower power and smaller antenna requirements, a wider usable spectrum, and greater security in message trans-

Part of the automatic message handling equipment used in the meteor burst communication system. G. R. Ochs (*left*) checks incoming teletype signals on the oscilloscope. Glen F. Miller (*right*) watches the low-speed tape recorder which takes messages off the tape and puts them on the teletype machine.

fer. Because of the highly directive character of meteor burst reflections, there is less jamming and interference caused by reception of signals from other transmitters.

Operation of the System

In the Bureau's system, two magnetic tape recorders handle the storage of incoming and outgoing messages at each transmitting-receiving station. Normal teletype messages to be transmitted are first recorded on magnetic tape and then sent at high speed. Received messages are recorded on magnetic tape at high speed and then printed at normal speed.

The system's control equipment determines when conditions are acceptable for transmission of messages. This decision is based on: (1) The amplitude-versus-time characteristics of the received signal; (2) the modulation of the received signal; (3) the availability of storage space for incoming messages; and (4) the availability of messages for transmission. In order to measure attenuation on the two oppositely directed radio paths, the transmitters at both stations are kept in continuous service.

With both transmitters on the air, the system can detect the presence of a suitably located meteor trail within a few thousandths of a second. When either station "hears" a signal reflected by a meteor trail, it shifts its transmitting frequency, thus indicating to the other its readiness to transmit messages. After both stations have received this signal, message transmission is initiated.

Should either terminal run out of magnetic tape or should the signal strength fall too low, the two stations "converse" with each other and agree to stop transmission temporarily.

At the end of a meteor burst, signal fading or obvious error in received messages causes the system to stop transmitting, and the transmitters return to their original frequency. Under normal conditions, the command to start and stop and associated events are so timed that no messages are lost.

The experimental meteor burst system was designed for a study of two-way communications over paths from 400 to 1,200 miles in length. Preliminary tests were made over a 390-mile path from Sterling, Va., to Walpole, Mass. However, an 800-mile path from Kilbourne, Ill., to Erie, Colo., was used in most of the investigations. At the field sites the equipment was housed in 24-ft trailers.

Equipment

The system's receivers are double-conversion superheterodynes. Each contains an FM detector for messages and an AM detector to measure signal strength. With each change in speedup ratio, the transmitter frequency shift is changed. Then it becomes necessary to match this change by a change in the electromechanical filter in the receiver. This filter sets the receiver pass band to correspond to the modulation. Another filter, located between the antenna and the receiver, rejects signals from the system's adjacent transmitter—an unavoidable source of disturbance because of its proximity to the receiver. With this filter (a quarter-wavelength resonant-line tuned circuit), it is possible to operate with only 480 kc difference between receiver and transmitter frequencies.

The transmitters are commercial units intended for base station use in mobile communication service. They were operated at 49 mc with a power output of 2 kw. Frequency control is by a d-c coupled, frequency-modulated exciter. The deviation of the transmitter is adjustable so as to provide shifts of 800, 2,000, 3,700, and 5,000 cps at the output frequency.

The antenna system is composed of two arrays, each consisting of 2 five-element Yagi antennas. To reduce the effect of a strong local transmitter on the sensitive receiving system, one array is always used for receiving, the other for transmitting. Also, contrary to the usual convention, the 2 antennas of each pair are fed out of phase to produce a split-beam pattern with a null on the great circle connecting the stations. This arrangement made it possible to aim the signals at directions most suited to the meteor burst path, inasmuch as most meteoric propagation takes place on either side of the great circle path. The antenna design is based on meteoric ionization at an elevation of 110 km.

"Noise" on a strip chart looks very much like signals received from meteor trail reflections. Robert J. Carpenter (seated), head of the meteor burst communication project, and Gerard R. Ochs, study samples of both kinds of signals.

Performance

Because of the complexity and high-speed operation of the system, automatic monitoring devices were used to analyze its performance. This was found to vary considerably with equipment settings and atmospheric conditions. For instance, from 1:00 p.m., May 8, until 12:30 a.m., May 29 (1958), 122,800 characters came over the Kilbourne receiver with only five errors—an error rate of 0.004 percent at 30 words/min. This record was in contrast to an error rate of over 10 percent in the small number of characters received under the worst conditions of thunderstorm and precipitation static. The characteristics of the signals received during the experiment indicate that it is advantageous to operate intermittently at transmission speeds higher than the average signaling rate.

Varying the operating threshold and speedup ratios constituted one phase of an investigation of the system parameters. Analysis of the data indicates that error rates can be reduced significantly by rejecting certain portions of the meteoric signals.

From the data on speedup ratios, it appears that the system operates most effectively at 2,400 words/min (40 times normal teletype speed). With this speed and a suitable operating threshold setting, a daily average of 40 words/min may be expected at a character error rate of 0.35 percent. Higher transmission rates should give better results if improved control systems and rapid-access storage facilities can be substituted. At lower transmission rates, noise interference is a greater factor as the signals have to remain error-free for a longer period of time for transmissions to be successfully terminated. This results in an increase in the probability of error.

The experiments indicate that signals from two coexistent meteor trails occur frequently enough to be a serious source of error. The system is also seriously affected by electrical storms, precipitation static, and nearby ignition systems and power lines. Other sources of interference are ionospheric forward scatter, sporadic *E*-layer propagation, and at the higher-latitude installations, auroral-reflected signals. Tropospheric scatter signals are a problem, but only over fairly short paths, 100 to 200 miles in length. To avoid these sources of interference, the Bureau recommends that a practical meteor burst communnication system contain an automatic device for setting the system's threshold at a fixed margin above the short-term median signal strength.

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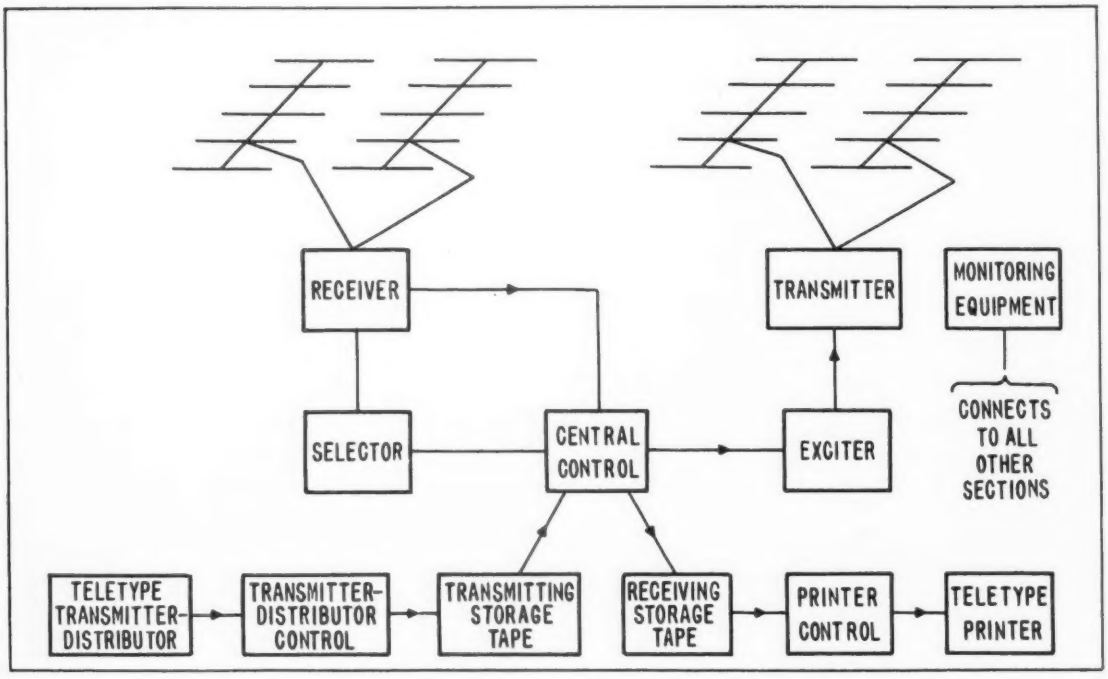
[1] Forward scatter of radio waves, *NBS Tech. News Bull.* **40**, 8 (*Jan. 1956*).



Block diagram of the intermittent meteor burst communication system.

ARCTIC RADIO COMMUNICATION CONFERENCE

OVER 250 scientists and engineers from industry, universities, and Government participated in the first Conference on Arctic Radio Communication, held March 4–6, 1959, at the Bureau's Boulder (Colo.) Laboratories. Foreign representation included Canada, Great Britain, the Air Defense Technical Center of the Supreme Headquarters of the Allied Powers in Europe (The Hague, Netherlands), and, by communication, the Norwegian Defense Research Establishment.

Current defense needs require a better understanding of arctic radio communication problems. Objectives of the conference, sponsored by the NBS Central Radio Propagation Laboratory, were to review the results of current arctic radio research, to discuss engineering problems encountered in designing effective arctic communication systems, and to foster a better understanding of arctic radio wave propagation.[1] R. C. Kirby of the Boulder Laboratories served as conference chairman.

After Dr. F. W. Brown, Director of the Boulder Laboratories, welcomed the group, Dr. C. T. Elvey, head of the Geophysical Institute, University of Alaska, addressed the first technical session. He described studies of the scatter and reflection of radio waves at oblique and vertical incidences from the ionosphere, and field-intensity investigations at various frequencies, including transpolar work between Alaska and Norway. Dr. Elvey reported an experiment in which three Doppler recording stations on artificial earth satellites were used, and he outlined radio astronomical techniques employed in studying ionospheric absorption and scintillation. A study of radio wave interaction at frequencies of several megacycles is now in progress at the University to obtain information on the electron density and electron collision frequency over a height range of from 50 to 80 km.

H. S. Marsh described the Air Force Cambridge Research Center's propagation research program. Four stations are in operation at Fairbanks, Alaska, and Thule, Greenland, for synoptic studies of transmissions from oblique sounders. Ionospheric backscatter methods are used in Alaska to determine electron density profiles in the ionosphere. An "in-house" program at the Cambridge facility is under way to measure distribution of high frequency (hf) signals received from the Thule backscatter sounder.

In a paper summarizing very high frequency (vhf) and ultra high frequency (uhf) radar studies of the aurora, by R. L. Leadabrand and A. M. Peterson (Stanford Research Institute), it was pointed out that results thus far have shown no perfect correlations between visual aurora and radio aurora because of the geometry of reflection of aurora echoes. These echoes occur most frequently when a radar ray intersects the earth's magnetic field at right angles and at ionospheric heights. In Alaska, two distinct types of echoes have been discovered: discrete echoes during the night, and diffuse ones during the day.

R. C. Kirby presented a paper coauthored by T. N. Gautier and A. D. Watt (NBS Boulder), which included a summary of studies for the Navy and Air Force. Nine sounding stations in the arctic and antarctic have furnished synoptic observations of ionospheric critical frequencies and reflection heights necessary in providing basic data to predict useful high frequencies, and for the study of blackouts and ionospheric characteristics at high latitudes. Field strength studies carried out in several frequency ranges have yielded information on: (1) The distribution of auroral zone absorption; (2) the attenuation over permafrost and glaciated areas as compared with attenuation over sea water; and (3) low frequency (lf) ionospheric reflection coefficients.

In this research, atmospheric noise studies have been made in several arctic areas at frequencies from the very low frequency (vlf) through hf, and parametric studies are being made of two ionospheric, long-range communication systems: Forward scatter and meteor burst. A study is planned to determine the relationship between zenithal absorption measurements at vhf and attenuation over oblique-incidence hf paths. An analysis of these measurements will be recommended for inclusion in basic data for revising maps of auroral zone absorption, and in engineering calculations involved in accounting for this absorption.

Because unusual transmission ranges with vhf were experienced in Canada, a team of Army Signal Corps engineers established an experimental base in Little America to study ground characteristics in polar regions. C. E. Sharp and A. H. Waite (U.S. Army Research and Development Laboratory) reviewed the results of operational studies made thus far by this team on the different causes of propagation losses.

W. Donaldson of the International Telephone and Telegraph Laboratories reported on propagation phenomena observed during DEW line operations over the past 2 years. With electronic equipment operating from lf to 1,200 Mc (uhf), six sets of observations were recorded. They were: Tropospheric scatter communications coverage due to ducting effects; vhf mobile communications interference effects and long-range phenomena; uhf and vhf air-to-ground absorption and coverage effects; ionospheric scatter communications, multipath back scatter, and cosmic noise effects; performance of hf point-to-point communications systems; and L-band radar, long-range detection, and overlap interference effects.

In analyzing the performance of hf polar-region com-

munication circuits, W. R. Vincent, R. L. Leadabrand, and A. M. Peterson (Stanford Research Institute) found that periods of high propagation outage correspond to periods of high magnetic activity; however, there is no definite correlation between them. Several methods for reducing basic outage were investigated in this work, including meteor-burst communication at vhf, the use of lf, nongreat circle propagation paths, and sweep frequency sounders.

The interest of the Voice of America (VOA) in arctic radio propagation was described by G. Jacobs of the U. S. Information Agency. Short-wave broadcasts by VOA to Europe and Asia were hampered by the geographic location of the northern auroral zone and the electronic barrier created by the zone's emphatic skewing over North America. To bypass the area, an extensive network of relay transmitters was established. However, many of these transmitters required installations on foreign soil. The VOA is, therefore, supporting a number of auroral propagation research programs in anticipation of the eventual use of the transauroral path for United States broadcasts to the Eastern Hemisphere.

Colonel W. E. Geyser (Headquarters, North Atlantic Airways and Air Communications Service, Westover Air Force Base, Mass.) evaluated the different means of radio communication used by his service as to overall reliability, flexibility, and propagation reliability. He listed troposphere-scatter methods as most effective, and then in descending order, lf, ionospheric scatter vhf (32–38 Mc), and hf methods. He noted that lf (42–180 kc) propagation was actually enhanced during arctic blackouts. Colonel Geyser emphasized the need for a communication system with the highest possible propagation reliability and jamming resistance, over ranges of at least 3,000 miles, even though the system had restricted information capacity and speed.

Frequency engineering problems in arctic communications were reviewed by G. W. Haydon of the Department of the Army (now of the Boulder Laboratories). To solve these problems, he said, improved methods are needed for predicting signal strength, signal distortion, and ionospheric (F_2 and sporadic-E) noise, and for describing statistical variables. Mr. Haydon also cited a need for additional data in reports of observations.

A paper was submitted by F. Lied, director of the Norwegian Defense Research Establishment which reported ionospheric studies in and near the auroral zone. These studies were undertaken to investigate forward scatter, drift and fading, auroral reflections, absorption, D-region during blackouts, vlf and lf recordings, and sporadic-E ionization.

In the opening session on the second day, Jacques Reneau of Cornell University discussed the phenomenon of spread-F. From studies of the mechanism by which energy is backscattered from ionized irregularities stretched along the earth's magnetic field, he has derived a theory to clarify the main features of equatorial spread-F. The theory is based on the delay time associated with rays from an ionospheric sounder to positions of perpendicularity with the magnetic field in the F-region. In its present form the theory does not yield a satisfactory explanation of arctic spread-F. Mr. Reneau suggested that an investigation be made simultaneously with ionospheric soundings, to determine the echo arrival angles when arctic spread-F conditions prevail.

J. L. Heritage, of the Smyth Research Associates, San Diego, California, indicated that some of the scatter signals observed in a survey of ionospheric signals received from a powerful 200-Mc transmitter might be useful for arctic communication purposes. He reported that signals resembling auroral propagation had been received on oblique transmission paths at a geomagnetic latitude of about 40 deg. Referred to as H_E scatter signals because of their connection with the earth's magnetic field at E-layer height, these signals have two forms, one a short burst-like form, and the other lasting up to 20 min.

B. R. Bean (NBS Boulder) told of studies to determine the effects of climate upon radio waves. One program is concerned with the development of an exponential reference atmosphere which will facilitate estimation of refraction effects in any region where surface weather observations are available. Worldwide maps have been prepared of the mean value of radio weather. Radiosonde observations are being studied to determine the occurrence of special radio phenomena such as ground-based radio ducts that make radio waves travel unusually long distances. In the tropics, the maximum observed incidence of ducts is 13 percent; in the arctic, 10 percent; in temperate zones, 5 percent.

A need for extensive investigations of path loss in tropospheric beyond-horizon radio relay systems was expressed by R. M. Hawekotte of the Bell Telephone Laboratories, Whippany, N.J. In summarizing path loss measurements made on tropospheric scatter communication systems, he reviewed the current status of tests at frequencies ranging from about 100 Mc to more than 4,000 Mc. An evaluation of published results reduced to 800 Mc showed the observed path loss to be about 10 db greater in winter, indicating a seasonal variation.

A statistical method, devised by A. P. Barsis, K. A. Norton, and P. L. Rice of the Boulder Laboratories, was described for predicting the performance of long-distance tropospheric communication circuits. The prediction is in terms of the probability of obtaining a specified grade of service for various percentages of time. The grade of service is determined by the minimum acceptable ratio of hourly root-mean-square carrier to rms noise for the type of intelligence to be transmitted. As the method employs meteorological parameters, it is applicable to arctic communication problems. Calculations schemes and graphical aids may be obtained from the authors.

R. S. Kirby (NBS Boulder) told of recent studies on planning intersite paths for communication facilities. Short-tropospheric-scatter facilities, not necessarily in line-of-sight paths, can be used for relaying traffic between a long-distance terminal and a communication relay center. Over smooth earth, ranges well in excess of 100 miles can be realized; in mountainous terrain, knife-edge diffraction can be utilized to obtain similar ranges. With such distances possible for intersite communications, numerous near-optimum sites become feasible. The use of such sites would reduce the number of terminal relay facilities required, resulting in extensive savings both in cost of installations and in operations.

A study of the twinkling of radio "stars", conducted at the University of Alaska, was described by Dr. C. G. Little (NBS Boulder). Discovered a decade ago, this phenomenon is caused by irregularities in the density of the ionization in the earth's upper atmosphere. The study showed differences between high- and low-latitude radio-star scintillations. For example, the scintillations were found to be more intense in Alaska than in England, and to occur throughout the day and night, rather than at nighttime only. The intensity of the scintillations was found to be relatively insensitive to the elevation of the source above the horizon.

J. H. Crysdale (Defence Research Telecommunications Establishment, Ottawa, Ontario) said one of the problems encountered in operating the Canadian meteor burst system on a circuit in the auroral zone during 1958 was blackout associated with solar flares. Because of this phenomenon, the circuit was not usable for 2 days during the month of July. Results of other studies indicate that the meteoric signal does not predominate during much of the time. A deeply fading signal of almost constant peak amplitude, associated with moderate error rates, is often obtained. Also observed were rapidly fluctuating signals of considerable amplitude, probably from the aurora.

During periods of great arctic disturbance, vlf is the least disturbed mode of propagation. Thus, despite its disadvantages, its use as a backup system is warranted. R. H. Doherty of the Boulder Laboratories gave an analysis of vlf data obtained from three radio stations monitored on winter flights in the Greenland region. Signals which had traversed the icecap were not excessively attenuated, but flights over the cap indicated a large directional effect, attributed to the use of a trailing wire antenna and a large wave tilt from the low conductivity of the icecap.

A summary was given of the results obtained by A. D. Watt, E. L. Maxwell, and E. H. Whelan of the Boulder Laboratories, in a study of the very low ground conductivities of arctic areas, and the particular ionospheric conditions prevailing at high latitudes, which can lead to unusual radiation and propagation conditions. Measurements from both the earth's surface and from aircraft were made of field intensities from transmitters located in the Labrador and Greenland areas. Great attenuation was observed when the initial portion of the propagation path was over icecap or permafrost. When the propagation path extended out over sea water, marked recovery in field intensity took place after the coast line was crossed. Estimates of skywave intensity agreed with observed results, provided the radiated field pattern was suitably modified by the antenna cutback factor. It was concluded that in arctic regions the siting of lf stations several miles inland may cause a great increase in total transmission path loss.

J. M. Weldon, of the Bureau's radio propagation field station at Ft. Belvoir, Va., described the present radio forecasting methods used at his station to service the general North Atlantic Path. He told of the need for specific path forecast mechanisms to be used in higher-latitude circuits, which are more susceptible to geomagnetic disturbance. He discussed efforts to find useful relationships that can be applied toward predicting maximum usable frequencies (MUFs) as well as radio quality. Correlative studies have been completed between F_2-layer critical frequencies at probable control points of several paths, and solar activity indices, magnetic indices, and radio quality data. From the results it was concluded that large negative deviations are readily associated with predictable magnetically active periods. However, few encouraging relationships were found involving magnetically quiet-period f_0F_2 variations.

M. E. Nason, of the Bureau's radio propagation field station at Anchorage, Alaska, explained how the effectiveness of radio disturbance forecasts could be improved by more accurate observations of MUF. In reviewing the communication problems of Alaskan and North Pacific areas, he described how data, obtained from the network of ionospheric vertical sounding stations located in the auroral zone and on the polar cap, are used to deduce propagation conditions and to judge the severity of radio disturbance.

In the first paper given on the final day of the session, J. W. Craig (Lincoln Laboratory, MIT) reported on a study undertaken to determine the effect of disturbed conditions on the fading-correlation between frequencies spaced by particular intervals. Signals were transmitted at these spaced frequencies between Thule and Ipswich, Mass., and from the data some indication was obtained of the "correlation separation." The results of the study are expected to be useful in determining possible new communication systems designed to operate under disturbed conditions.

According to L. Owren, H. Bates, and R. Hunsucker of the Geophysical Institute, University of Alaska, oblique incidence sweep-frequency backscatter sounding of the arctic ionosphere, over the frequency range 1–25 Mc, has shown a prevalence of anomalous echoes. A direct F-layer echo is observed regularly which is associated with electron density irregularities at actual heights between 350 and 600 km. The relative signal strengths of fixed frequency pulse transmissions on 12, 18, and 30 Mc from Alaska, recorded at Kiruna, Sweden, have been compared with simultaneous ground-scatter echoes received in Alaska from the polar region.

Analysis of the data recorded for the month of December 1958 shows that the 12- and 18-Mc signals are propagated by two- and three-hop modes as well as by a one-hop tilted layer mode. The two-hop mode is principally a daytime mode (Alaska time) while the dominant three-hop mode occurs both day and night. Minimum received signal and polar groundscatter are observed at the time of maximum *D*-layer absorption for the outgoing radiation.

In reviewing some of the effects of the sporadic ionization derived from ionograms in the auroral zone, E. S. Warren (Canadian Defence Research Telecommunications Establishment) discussed the influence of spread-*F*, polar spurs, and forked records phenomena on hf point-to-point communication. He outlined methods for improving long-term MUF and usable frequency (LUF) predictions and the handling of statistical variations, and suggested that information be disseminated to the operators as soon as it is produced from a few oblique incidence sounders.

H. Leinbach and G. C. Reid (Geophysical Institute, University of Alaska) reported that, with IGY absorption data, anomalous absorption in the lower ionosphere can be classified into two types—aurorally associated absorption (Type II), and absorption arising from ionization of the lower ionosphere by charged particles from solar flares (Type III). Type II is strongest at the southern edge of the auroral zone and is at a maximum during the postbreakup aurora, often reaching hourly average values in excess of 2 or 3 db at 27 Mc. As a result, hf communication would become impossible at normally attainable powers. Although less frequent, Type III is of considerable importance since it may cause complete absorption of hf waves over the entire polar region north of 65° geomagnetic latitude. During the years of sunspot maximum, 6 to 8 of the Type III events may be expected to occur each year.

D. K. Bailey (Page Communications Engineers, Inc., Washington, D.C.) discussed lower ionospheric abnormal ionization, associated with cosmic-ray flux enhancements, in terms of the great solar event of February 23, 1956. He described two kinds of abnormality: *Early effects* observable in the dark hemisphere at the time of the sudden cosmic-ray enhancement, and *late effects* which begin gradually and reach a maximum in a few hours.

The early effects are explained as a consequence of a plausible difference in composition between streams of solar particles of cosmic-ray energies and ordinary cosmic rays. The late effects are explained in terms of ionization produced in the lower ionosphere (30 to 110 km) by the passage or stoppage of solar particles, mostly protons. An interesting byproduct of the investigation was an evaluation not only of the coefficient of collisional detachment of electrons from negative ions, probably O_2^- for the most part, but also of the negative-ion-to-electron ratio, and the effective recombination coefficient *at night* between 30 and 110 km.

In hf communication in the arctic region, the transmission frequency is normally decreased during disturbed periods as the F_2 MUF is usually depressed at these times. In a paper by R. M. Gallet, H. I. Leighton, and E. K. Smith (NBS Boulder), the use of sporadic-*E* was advocated to back up medium-distance hf circuits (1,000 to 2,000 km), even during the polar blackouts. However, to make the best use of sporadic-*E*, the transmission frequency must be increased instead of reduced. E_s data from the worldwide network of ionosphere sounders indicate that sporadic-*E* in the auroral zone tends to be most prevalent near the maximum occurrence of aurorae and in the neighborhood of geomagnetic midnight.

O. G. Villard, Jr., and K. C. Yeh of the Radio Propagation Laboratory at Stanford University suggested that radio voice messages, normally garbled by auroral flutter fading, would be considerably improved if they were transmitted at a higher-than-normal rate, followed by a corresponding slowdown on the receiving end of the circuit. This technique would reduce the effective speed of the fading of the individual frequency components of the voice signal, and thus improve intelligibility, since voice quality of amplitude-modulated transmissions falls off rapidly when the average carrier fading speed becomes higher than about 10 cps. However, the method will be useful only when adequate signal-to-noise ratios are initially present.

Dr. K. Davies (NBS Boulder), in discussing the importance of the sweep-frequency pulse technique (generally used in vertical incidence ionospheric soundings) in solving radio propagation problems, said an understanding of the relationship between vertical incidence and oblique incidence data is needed, as well as ionospheric soundings for the midpoint of the circuit. The three Greenland stations—Thule, Godhaven, and Narsarssuak—in satisfying these requirements, provide a unique opportunity to investigate radio propagation in a normally inaccessible area.

G. E. Hill of AVCO Research and Advanced Development Division, Wilmington, Mass., reported critical frequency studies based on maps collected from all available Northern Hemisphere ionospheric sounding stations. The maps showed the monthly medians of f_0E and f_0F_2 for January, March, and June 1957. As expected, the results indicate that the daytime f_0E follows a cosine dependence on the solar altitude. The f_0F_2 generally decreases toward high latitudes, forming a "polar low". This low, more extensive in winter than summer, moves around the globe at high latitudes following the sun. The high daytime winter values of f_0F_2 in auroral latitudes are related to the position of the low. Evidence of solar tidal effects was found. A synoptic series in July 1957 showed that features apparent on a monthly average are also present on a daily basis. However, the daily features of f_0F_2 indicate some important departures from the monthly median variations.

V. L. Agy (NBS Boulder) told of recordings made over a 9-month period (April–December 1958) of continuous wave radio transmissions (at 8 Mc) that emanated from Maui, Hawaii, and Bismarck, N.Dak., and were received at stations in Anchorage and College, Alaska. According to present methods of calculating

field strength, the Maui paths should show no auroral zone attenuation, and the Bismarck signal should be about 30 db weaker at College than at Anchorage.

The data showed the Maui paths to be relatively free of auroral zone effects; however, the Bismarck signal received at College was attenuated only about 10 db relative to that received at Anchorage. The results indicate that, in addition to the greater attenuation over the Bismarck paths, field strength values for a given hour during a month show much greater dispersion for the Bismarck than for the Maui paths. Also, correlations between field strength values for any pair of the paths are higher than would be expected for temperate zone paths.

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[1] *For further details, see* Conference on Arctic Communication, *J. Research NBS* **64D**, *No. 1 (1960). The full proceedings of the Conference will not be published since it is expected that individual authors will submit papers to appropriate technical journals.*

44th National Conference on Weights and Measures

THE 44th National Conference on Weights and Measures, meeting in Washington, D.C., (June 8–12) unanimously approved the recent adoption of the International Yard and Pound, congratulated the Director of the National Bureau of Standards on the adoption, and urged the Congress of the United States to fix by statute these and other national standards of weights and measures.

Secretary of Commerce Lewis L. Strauss in the opening address of the Conference spoke of the effect of weights and measures administration on the economy of the nation. He also told the delegates of the present economic situation of the nation. Secretary Strauss told of his desire to strengthen and expand the activities of the National Bureau of Standards.

Other speakers contributing to the Conference program included: The Honorable Genevieve Blatt, Secretary of Internal Affairs, State of Pennsylvania; John O'Neill, State of Kansas; W. C. Boyd, State of Indiana; M. H. Neustadt (delivering address of Dr. Lawrence Zeleny, Chief, Standardization and Testing Branch, Grain Division, U.S. Department of Agriculture); R. A. Findlay, State of Alaska; the Honorable B. J. Butler, Commissioner of Agriculture, State of Kentucky; C. R. Moore, Legal Advisor, Bureau of Investigation, Federal Trade Commission; D. W. Masters, Director, Consumers Union, Mount Vernon, New York; J. L. Harvey, Deputy Commissioner, U.S. Food and Drug Administration; Louis Krach, Ingenieur en Chef des Instruments de Mesure, Ministry of Industry and Commerce, Paris, France; W. I. Thompson, Monmouth County, New Jersey; C. L. Jackson, State of Wisconsin; and D. L. Bowman, Chief, Packers and Stockyards Branch, Livestock Division, U.S. Department of Agriculture.

During the Honor Award Ceremony, 2 delegates received certificates for having attended 25 Conferences, 7 for having attended 20 Conferences, 9 for having attended 15 Conferences, and 18 for having attended 10 Conferences.

The balance of the program was devoted to the presentation of technical papers, committee reports, and general discussion. Total registration was 389. Members were present from 39 states, the District of Columbia, and Puerto Rico.

Conference Chairman C. M. Fuller, Secretary of Commerce Lewis L. Strauss, and Dr. A. V. Astin, Director of the National Bureau of Standards (left to right), at the opening session of the 44th National Conference on Weights and Measures.

The Conference, which was organized in 1905, serves as a clearing house for weights and measures information, and brings together weights and measures officials as well as representatives of business and industry. Model laws, specifications, tolerances, regulations, and enforcement practices are recommended by the Conference for adoption by the various States, which have the legal responsibility of regulating commercial weighing and measuring devices, and of controlling commercial transactions involving quantity. The National Bureau of Standards, through its Office of Weights and Measures, cooperates with the states in this endeavor by providing reference standards, calibration service, and a wide range of technical advisory programs. Thus, the national standards of length and mass, which are in the custody of the Bureau, are translated into everyday use.

In other actions, the Conference approved the solicitation of the technical assistance of the National Bureau of Standards and the several organizations representing manufacturers of aerosol-type commodities to develop meaningful statements of quantity for such products and reasonable methods of checking such statements; also, a completely revised model state weights and measures law was adopted. Copies of the law are available, without cost, from the Office of Weights and Measures, National Bureau of Standards, Washington 25, D.C.

Officers of the Conference for the following year include A. V. Astin, *ex officio* president, W. S. Bussey (Chief, NBS Office of Weights and Measures), *ex officio* Secretary, and the following who were elected: Chairman, H. E. Crawford (Jacksonville, Fla.); Vice Chairmen, R. M. Brodenweiser (Mercer County, N.J.), H. N. Duff (Colo.), J. I. Moore (N.C.), W. E. Shiehy (Fairfield County, Conn.); Treasurer, C. C. Morgan (Gary, Ind.); Chaplain, Ralph Magoffin (S.C.).

Publications of the National Bureau of Standards

Periodicals

Journal of Research of the National Bureau of Standards.
Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $4; foreign $4.75.
Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic $2.25; foreign $2.75.
Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic $2.25; foreign $2.75.
Section D. Radio Propagation. Issued six times a year. Annual subscription: Domestic $4; foreign $4.75.

Section C. Engineering and Instrumentation, Volume **63C,** *No. 2, October–December 1959.*

Conical coaxial capacitors and their advantages. M. C. Selby.
A photoelectric followup and recording system, and its application to remote observations of the beam in high precision balances. H. A. Bowman and L. B. Macurdy.
A stroboscopic vibration analyzer. S. Edelman, R. Brooks, S. Saito, E. Jones, and E. R. Smith.
Evaluation of lens distortion by the inverse nodal slide. F. E. Washer and W. R. Darling.
Evaluation of lens distortion by the modified goniometric method. F. E. Washer and W. R. Darling.
Proposed criteria for defining load failure of beams, floors, and roof constructions during fire tests. J. V. Ryan and A. F. Robertson.
Conductive flooring for hospital operating rooms. T. H. Boone, F. L. Hermach, E. H. MacArthur, and R. C. McAuliff.
Measurement of the aging of rubber vulcanizates. J. Mandel, F. L. Roth, M. N. Steel, and R. D. Stiehler.

Section D. Radio Propagation, Volume **63D,** *No. 3, November–December 1959.*

Radio-refractive-index climate near the ground. B. R. Bean and J. D. Horn.
Path antenna gain in an exponential atmosphere. W. J. Hartman and R. E. Wilkerson.
Effect of atmospheric horizontal inhomogeneity upon ray tracing. B. R. Bean and B. A. Cahoon.
Correlation of solar noise fluctuations in harmonically related bands. L. R. O. Storey.
A monochromatic low-latitude aurora. F. E. Roach and E. Marovich.
Pattern synthesis for slotted-cylinder antennas. J. R. Wait and J. Householder.
Central Radio Propagation Laboratory exponential reference atmosphere. B. R. Bean and G. D. Thayer.
Excitation mechanisms of the oxygen 5577 emission in the upper atmosphere. E. Tandberg-Hanssen and F. E. Roach.
Method for measuring local electron density from an artificial satellite. L. R. O. Storey.

Technical News Bulletin, Volume **43,** No. 10, October 1959. 15 cents. Annual subscription $1.50; 75 cents additional for foreign mailing.
Basic Radio Propagation Predictions for December 1959. Three months in advance. CRPL–D181. Issued September 1959. 10 cents. Annual subscription $1; 50 cents additional for foreign mailing.

Circulars

C601. Recorder survey: Recording surfaces and marking methods, G. Keinath. 30 cents.

Monographs

Mono 1. Energy dissipation by fast electrons, L. V. Spencer. 45 cents.

Technical Notes

Technical Notes are available only from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. (Order by PB number.)
Analysis of ionospheric vertical soundings for electron density profile data. I. Facilities for convenient manual reduction of ionograms, J. W. Wright and R. B. Norton. TN14 (PB151373) 50 cents.
Analysis of ionospheric vertical soundings for electron density profile data. II. Extrapolation of observed electron density profiles above $h_{max}F_2$, J. W. Wright. TN19 (PB151378) 50 cents.
Precise time synchronization of widely separated clocks, A. H. Morgan. TN22 (PB151381) $1.50.
Design of single frequency filters, F. F. Fulton, Jr. TN23 (PB151382) 50 cents.

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FREDERICK H. MUELLER, *Secretary*
NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, *Director*

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